SAND2013-8364C

Pushing the mobility limits on 4” MBE systems

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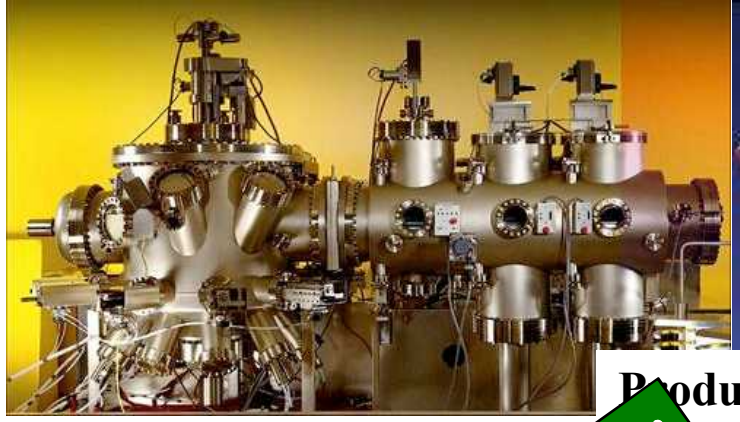
NAMBE 2013

The Art of MBE Workshop

Oct. 10, 2013, Banff, Canada

This work was performed, in part, at the Center for Integrated Nanotechnologies, a U.S. Department of Energy, Office of Basic Energy Sciences user facility. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



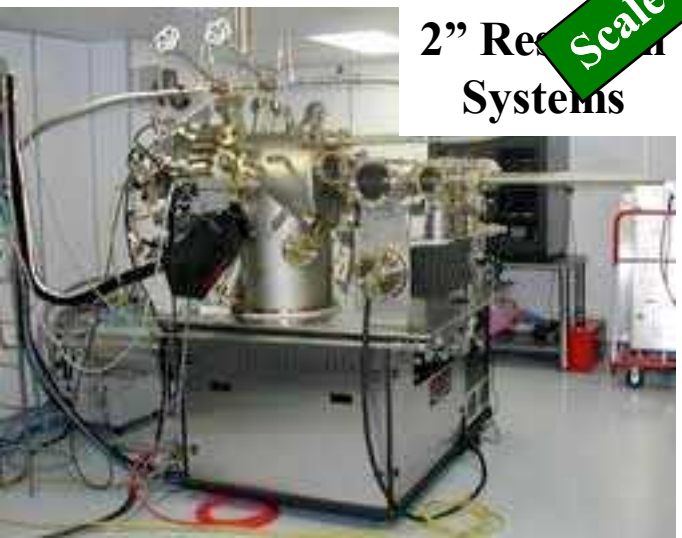
Production
Systems

Scale Down

4” MBE

Scale Up

2” Re[illegible]
Systems



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Strength & Weaknesses

- 2” Characteristics
  - Small, Compact
  - Short source-substrate dis.
  - Smaller cells

2” Strengths

- **Less Space**
- **Less Cost**
- **Lower cell temp**
- **Lower heat load**
- **Quicker adjustments**
- **Quicker stabilization**

2” Weaknesses

- **Fewer, smaller ports**
  - **Cells & others**
- **Small growth area**
- **Poor uniformity**
- **Small material capacity**
- **Poor flux stability w/time**

Strength & Weaknesses

- Production Characteristics
  - Large size
  - Big substrate-source dis.
  - Big cells

Production Strengths

- More, larger ports
  - Cells & others
- Large growth area
- Excellent uniformity
- Large material capacity
- Good flux stability w/time

Production Weaknesses

- Large Space
- Large Cost
- Higher cell temp
- Large heat load
- Larger material consumption
- Slower adjustments
- Longer stabilization

Interesting Note

2” Strengths

- Less Space
- Less Cost
- Lower cell temp
- Lower heat load
- Quicker adjustments
- Quicker stabilization

2” Weaknesses

- Fewer, smaller ports
  - Cells & others
- Small growth area
- Poor uniformity
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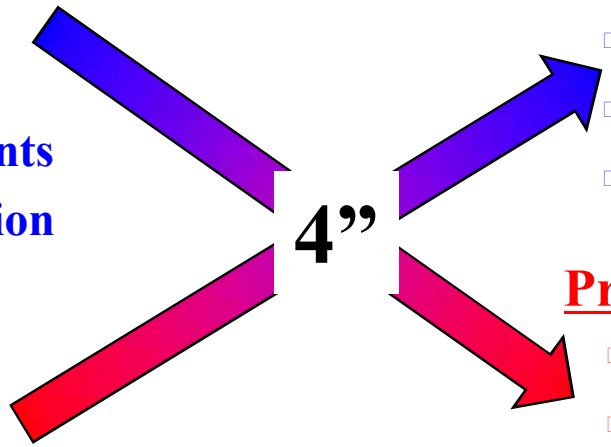
- Poor flux stability w/time



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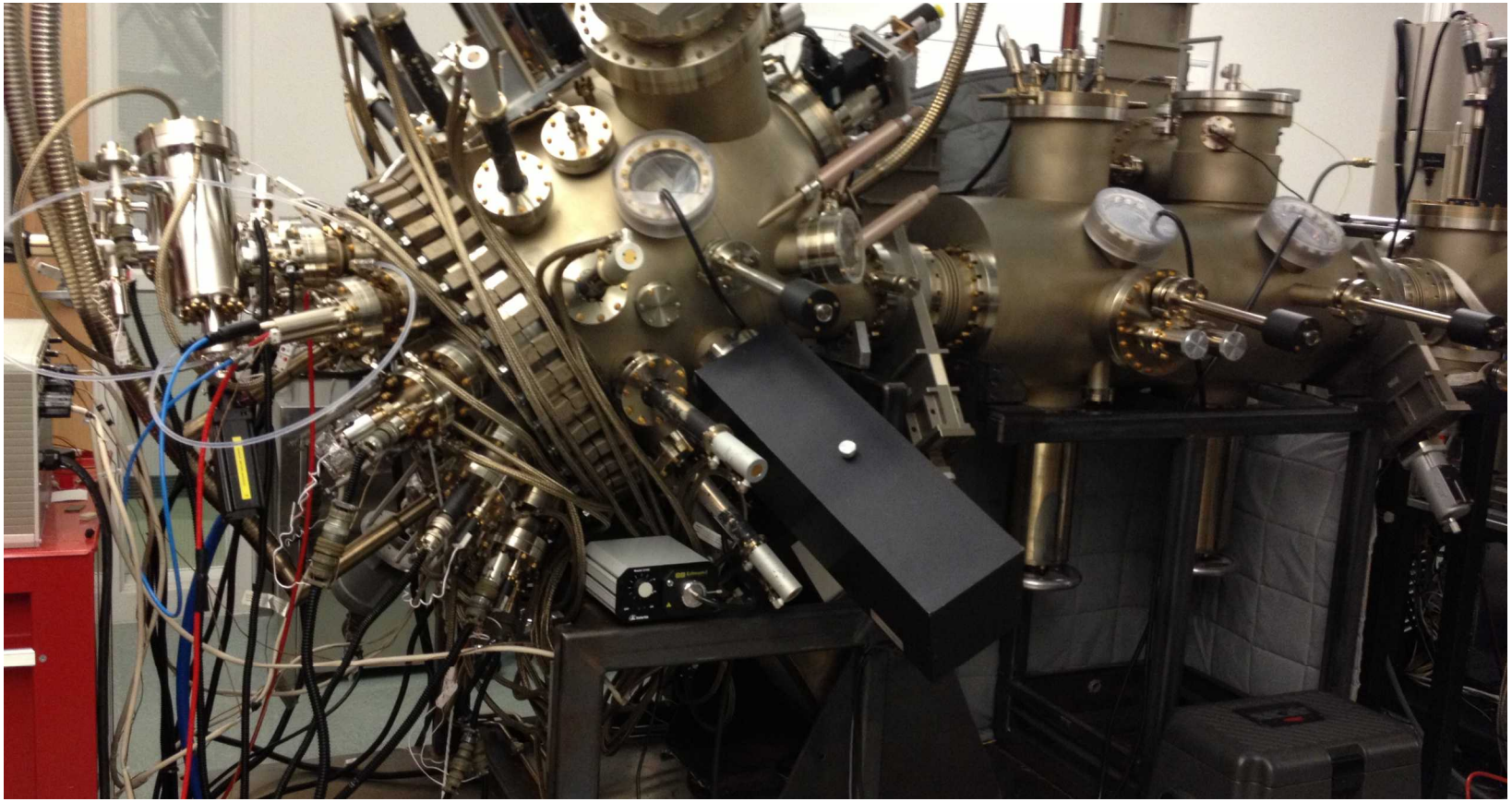
My Lab



EPI 1240: ~Research

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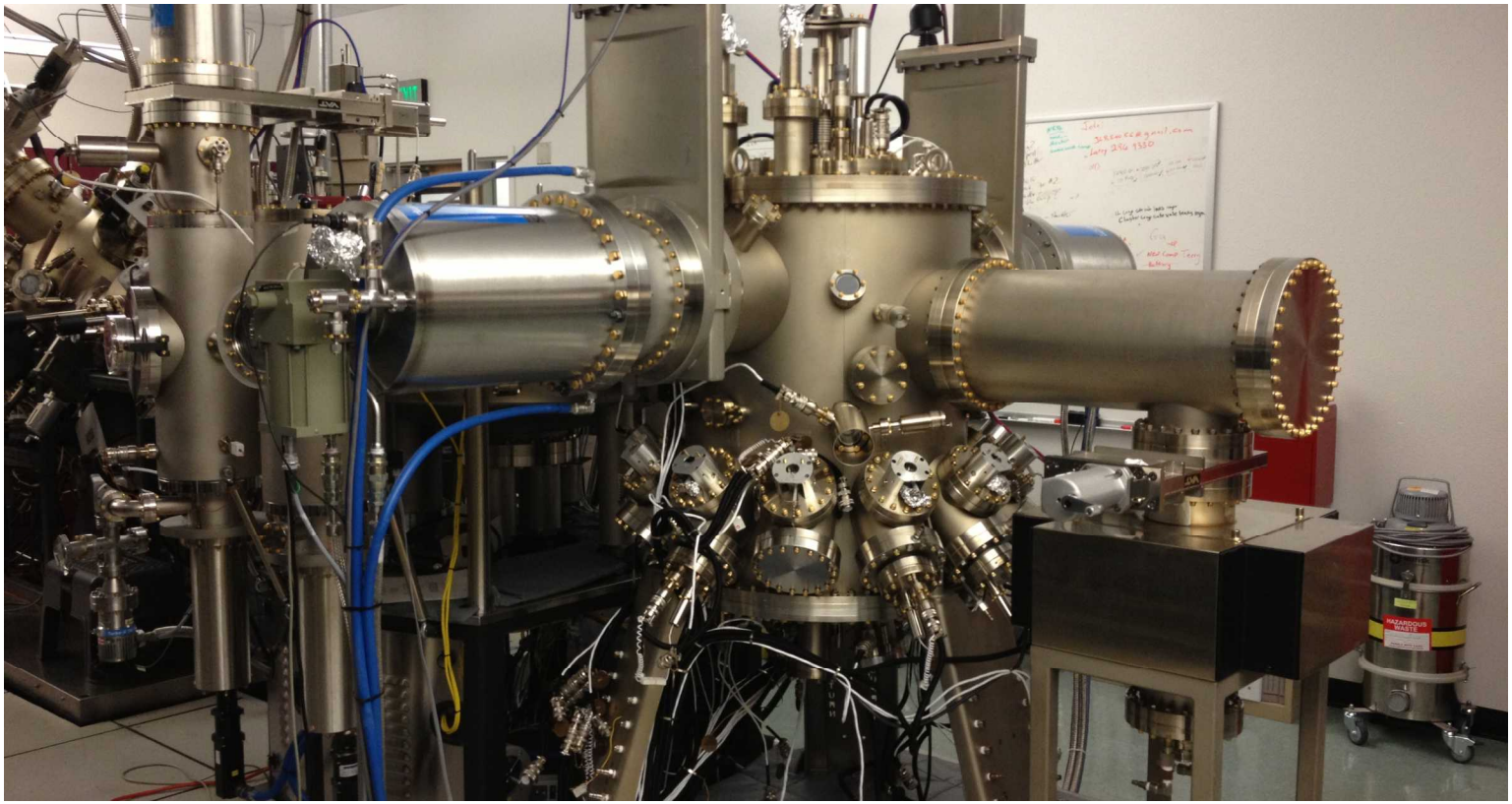
My Lab



Veeco GEN20: ~Production

Scaled down GEN2000

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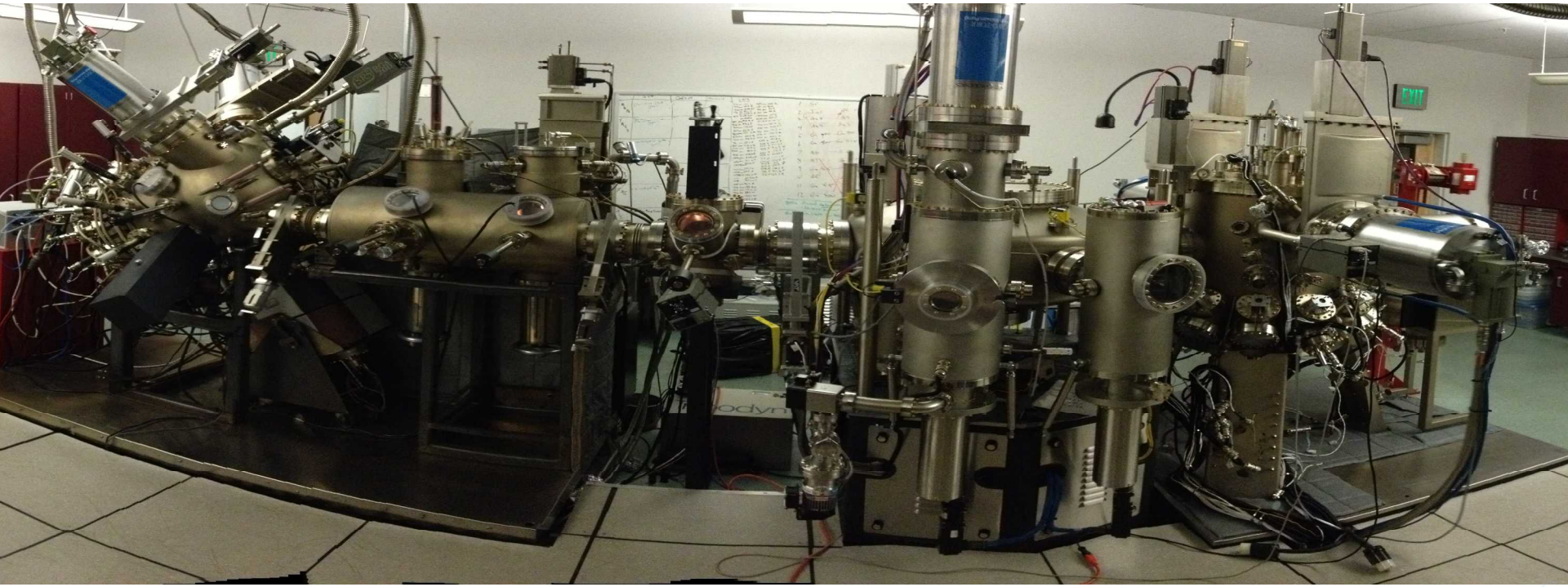
My Lab



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CINT is a DOE/BES National User Facility

- Access via competitive system based on scientific quality
- No-fee for pre-competitive research (Jointly owned IP)
- Full-cost recovery required for proprietary research (User owns IP)
- Collaborative research or just access equipment
- Flexible project duration, 18 month maximum, renewable
- Semi-Annual *Call for User Proposals* (March/September)
- Rapid Access Proposals for off-cycle, urgent research
- CINT cannot provide funding to users

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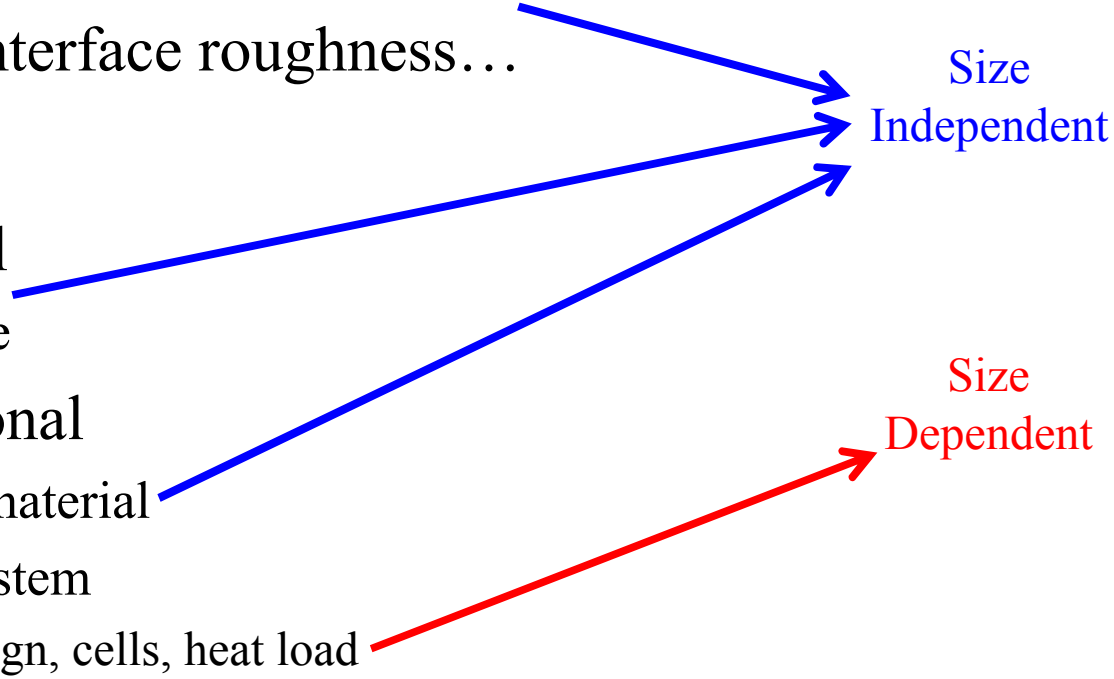
MBE at a User Facility?

- Access via competitive system based on scientific quality
- Also judged on feasibility
- Users don't actually run the machine themselves
- This past fiscal year – 40 User Projects
- Projects can be grouped
  - "High" mobility 2D electrons and holes for transport
    - Require high purity, reasonable precision.
  - Quantum cascade laser (QCL) primarily in THz
    - Require high precision, somewhat high purity
  - Other optical emitters and detectors
- All structures can be grown in either machine

  BUT there is a preferred machine
  - => Nitty-gritty of using/designing 4" machines

What limits mobility in 4” compared to 2”?

- Bulk Crystal Quality
  - Defects, interface roughness…
- Impurities
  - Intentional
    - Structure
  - Unintentional
    - Source material
    - MBE system
      - Design, cells, heat load



Source Flange Design

Design	1240	GEN20	
Cell Port #	12	12	
Cell Port Size	4.5”	4.5”	
Angle from Normal	34°	45°	
Source-Substrate Distance	10.55”	11.0”	**=> Cells run hotter than 2”**
Consequences			
Uniformity	±0.55%	±0.15%	

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Material Consumption (μm/g)

Cell Type	1240	GEN20
Ga 85cc (w/insert)	3.2	2.6
Ga Sumo (400g)	-	1.8
As (Mark IV)	0.9	0.6

This affects:

- **Length of campaign => material purity**
- **Cell stability during long growths**

Ga Load (g)	600-700	1600

Ga Cell Choice

Type	Load (g)	Backgrnd (/cc)	am Stabilize (hr)	Step Stabilize (min)
85cc w/insert	125	<upper e12	~0.5	10-15
Sumo 400g	350	mid e13	1-2	30-60
Sumo 900g	650	mid e13	3-4	don't bother

Consequences:

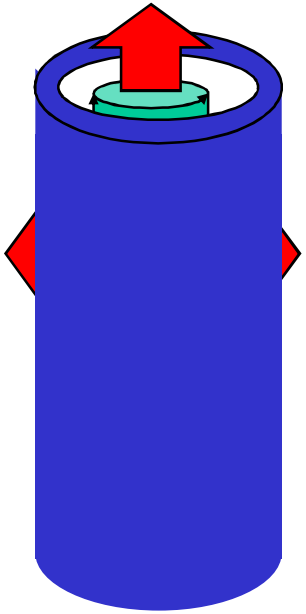
- **HiMo -> 85**
- **QCLs -> Sumo**
  - **Don't change Sumo, set other to it**
  - **Run 24hr during week**

Handling Heat

(To decrease impurities)

Still Heats

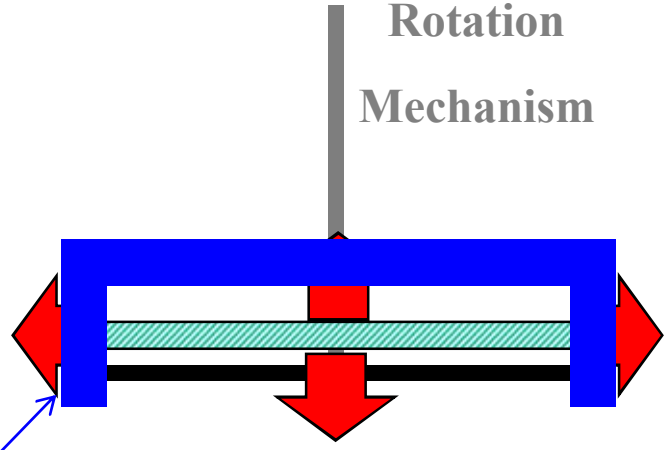
- **Closed Shutter**
- **Substrate**



Evaporation Heat

Water Flow

Cooling



Only in 1240

Still Heats

- **Anything in Front**

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1240 Source LN_2 Shrouds

substrate

Positives

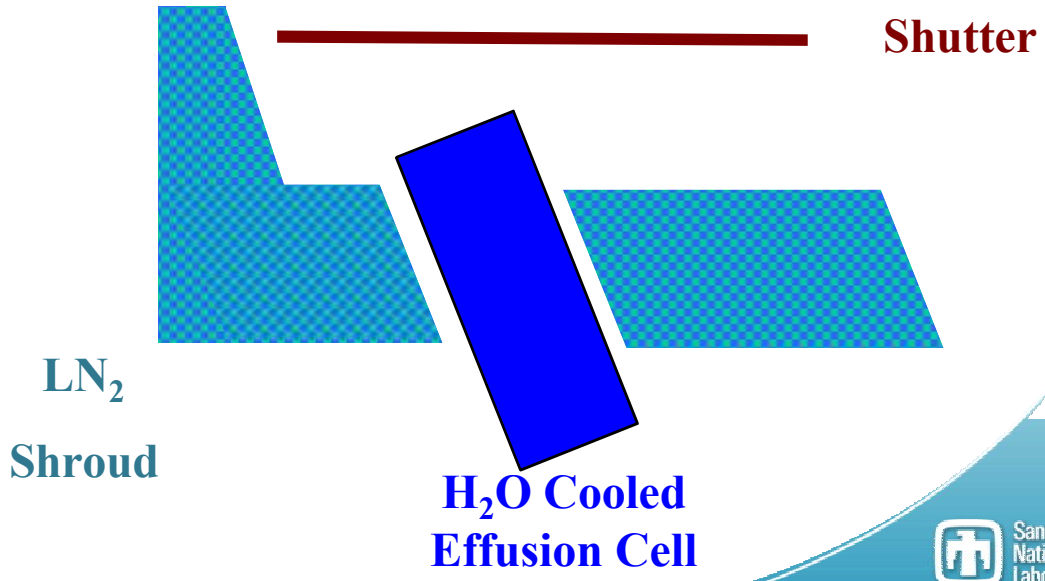
- Angled, "loose" shutter
  => minimal shutter transients
- Heated reflected to LN_2

Negatives

- Solid material build-up near cells
- Liquid (Ga) goes ??

Max Mobility

12 million



Gen20 Source LN_2 Shrouds

Positives

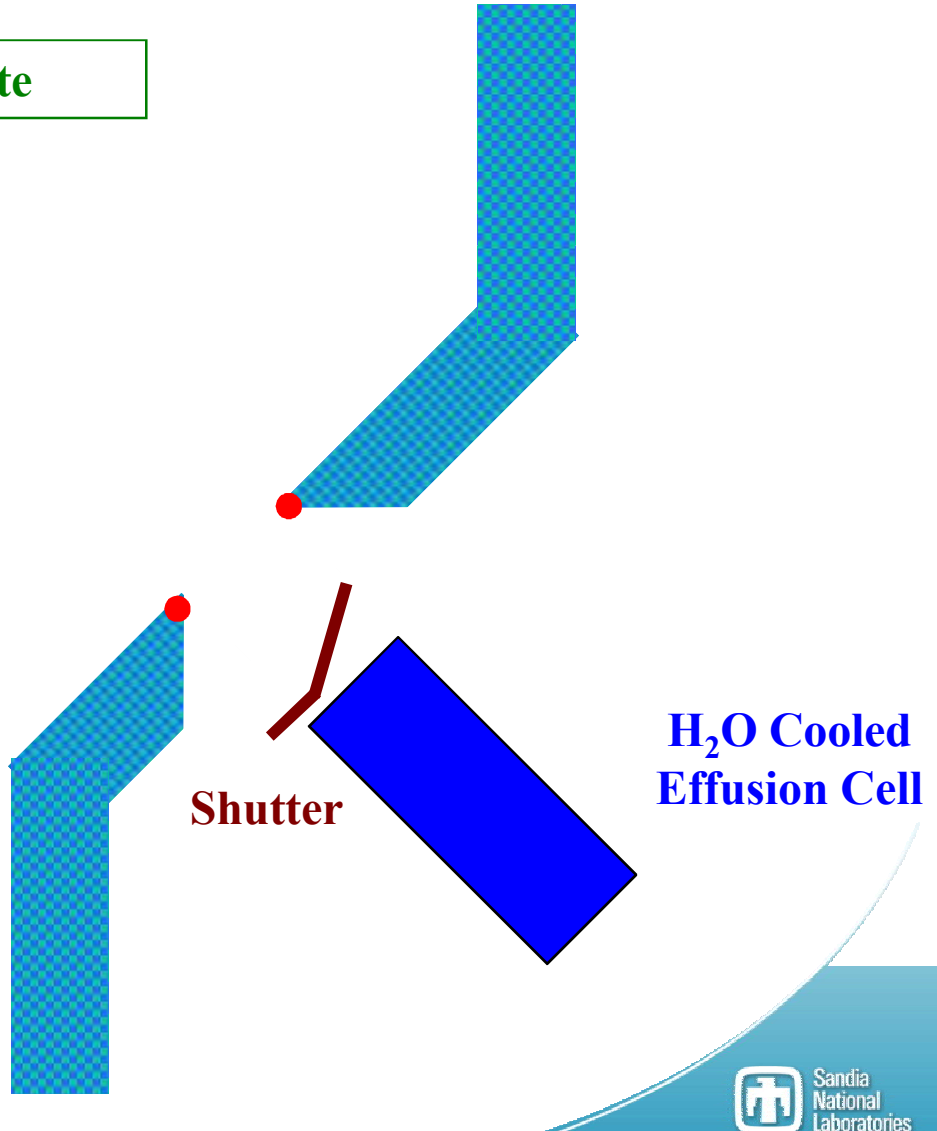
- Bent shutter
  => lowers shutter transients
- Cell behind LN_2
  => protected from flakes
- Heated reflected to LN_2

Negatives

- Material build-up above cells
- Liquid (Ga) drips on cell

Max Mobility

2 million



Which Project is Grown Where?

- Projects type
  - **"High" mobility 2D** electrons and holes for transport — **1240**
  - **Quantum cascade laser** (QCL) primarily in THz — **GEN20**
  - **Other** optical emitters and detectors — **Either**

4” High Mobility Summary

- 4” can not compete with 2” for maximum mobility.
- 4” can grow somewhat high mobility (12 million)
- 4” better than 2” for projects that require a lot of processing.

  - i.e. Gated quantum wires and dots

- Details of design affects optimal device choices and possible research directions.
- Small design details can make a lot of difference